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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application serial no.: 10/824,492
Inventor: Petter Muren
For: Rotor and aircraft passively stable in hover
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Sir:

Please find enclosed for filing:

- Certified copy of priority document
- Return receipt postcard

Please charge and any and all necessary fees during the pendancy of this application to deposit account 501898.

Respectfully submitted,
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According to document received on 2003.09.01 the application is assigned to Proxflyer AS

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Oppfinnelsens benevnelse: Rotor and aircraft passively stable in hover

Rotor and aircraft passively stable in hover

Field of the invention

The present invention relates to rotary wing aircrafts such as helicopters, and in particular to a rotor system that enables passively stable hover. It also relates to a coaxial rotor system specially suited for very small aircrafts and methods to control them.

Background of the invention

Typically, rotary wing aircrafts like helicopters are sustained by a rotor, rotating about a vertical rotor shaft, generating lift or upward thrust. The direction of thrust is perpendicular to the rotating plane defined by the path the tip of the rotor blades follows when they rotate about the rotor shaft.

In a conventional helicopter the total thrust from the rotor can be changed by collectively changing the pitch angle of all the rotor blades, thus controlling the helicopter in the vertical direction. The horizontal direction of flight may be altered by cyclically adjusting the pitch angle (or in short; the pitch) of the rotor blades. Cyclically adjusting the pitch, means that the pitch of individual rotor blades are adjusted from a maximum in a particular position of rotation to a minimum at the opposite side. This causes the lift in one part of the rotation to be larger than in other parts, whereby the rotating plane is tilted with respect to the rotor shaft axis. When the rotating plane is tilted like this, the initially vertical thrust also tilts and therefore gets a horizontal component, pulling the helicopter in the direction of the downwardly tilted rotating plane.

Normally, a helicopter must be actively controlled either by a pilot or from gyroscopic sensors. The necessary means to varying and controlling the pitch angle of each blade is complicated, expensive and add weight to the helicopter.

A fixed pitch rotor without individual blade control would enable a simpler and more light weight helicopter or aircraft. However, a fixed pitch rotor is inherently unstable in hover (remaining stationary in the air) and requires other means of control. There are several examples of helicopters with fixed pitch rotors including fixed pitch counter-rotating rotors, controlled by some kind of weight shifting.

US patent no. 06182923 discloses a helicopter where the rotor assembly is able to slide in the longitudinal direction of the fuselage, and at the same time it is able to tilt in the transverse direction. The purpose of this arrangement being to alter the center of gravity relative to the thrust from the rotor, thereby tilting the helicopter in the desired direction of flight. An other fixed pitch counter-rotating coaxial rotor helicopter is disclosed in US patent no. 06460802. In this helicopter the rotor assembly including the engine is pivotably connected to the fuselage and can tilt in any direction, thereby controlling the aircraft.

In several helicopters designed and built by Kaman Corporation, the inner part of the rotor blades have a fixed pitch similar to the rotors above, while they can twist in the longitudinal direction. On the Kaman helicopters the rotor blades are actively controlled by "servo flaps" adapted to twist the blades in order to cyclically change the pitch, thereby controlling the direction of flight.

Control of an aircraft with a fixed pitch rotor can also be achieved by operating vents or slots to alter the flow of air going through the rotor. An other alternative is to use 4 separate propellers, 2 and 2 rotating in opposite direction and placed diagonally about a central vertical axis. Each propeller initially producing an equal part of the vertical thrust needed to lift the aircraft. The aircraft is controlled by tilting it in the desired direction of flight, by increasing the thrust from a propeller on one side of the aircraft and reducing the thrust from the propeller on the opposite side. This idea was first realized in a full scale aircraft in 1920. A similar but very small toy aircraft,

battery powered and remotely operated, was introduced by Keyence Corporation, Japan in 1997.

The aircrafts described above are examples of simple designs, however, they are not passively stable and therefore need to be controlled by an experienced pilot or operator. Most of them are operated under light wind conditions or indoors.

A rotary aircraft passively stable in hover is disclosed in US patent no. 05297759. This aircraft is in fact a large single rotor including 2 small propellers mounted directly on the rotor blades in order to spin the rotor fast enough to produce the required lift. The hole aircraft spins, and the possibilities for direction control is limited. It is unclear how this rotor system could be used in a more conventional aircraft comprising a fuselage or a main body with a rotor connected to a vertical rotor shaft.

In many applications it would be desirable to have a helicopter-like aircraft that is stable without any form of active control, even if high forward speed and the ability to operate under windy conditions is sacrificed.

Summary of the invention

The present invention aims at fulfilling the needs for a passively stable rotary wing aircraft by disclosing a rotor of simple design, that makes it possible to build such an aircraft. Furthermore, this rotor could be used in a counter-rotating coaxial rotor system that is both light weight, efficient and easy to operate, ideal for small remotely operated electric powered aircrafts.

The rotor disclosed in the present invention has a generally fixed conical shape, a initially horizontal rotating plane and a rotor shaft with a vertical axis. The rotor is capable of generating the required lift to enable an aircraft to have sustained stable flight including passively stable hover. The present invention rely on three different means functioning together to control the stability and behavior of the rotor.

A first means, tiltably connects the rotor to the vertical rotor shaft, without allowing individual rotor blades to flap (move up and down) separately.

Secondly, the rotor is stabilized with respect to the aircraft by allowing a part of the rotor blades to have a fixed pitch relative to the rotor shaft axis. If the rotor has been tilted, the part of the blades with fixed pitch relative to the shaft will have different lift in the different parts of rotation, whereby the rotor is tilted back to its initial position.

Thirdly, in a rotor that moves horizontally the rotor blades will have different relative airspeed depending on where in the rotation they are. In the part of rotation where the blades rotate forward in the same direction as the movement, the relative airspeed increases. The increased speed give increased lift, that starts to tilt the rotor or more precisely the rotating plane. In the present rotor, at least an other part of the rotor blades have a fixed pitch relative to the rotating plane (this is in addition to the part of the rotor blades that have a fixed pitch relative to the rotor shaft axis). This is important, because it very much adds to the tilting tendency of the rotor and secures that even small movements will tilt the rotating plane and thereby also the vertical thrust. The tilted thrust has a horizontal component acting against the movement, trying to stop it.

The increased tilting tendency is actually the opposite of the normally desired behavior and limits the maximum achievable forward speed. However, when the movement stops, the first means stabilizing the rotor with respect to the rotor shaft, brings the rotor back to its initial position.

To protect and to support the rotor blades during operation, the blades, at their tip can be connected to a ring, encircling the entire rotor. This ring, due to its inherent weight will add to the gyroscopic stability of the rotor.

The present invention also discloses an aircraft that is passively stable in hover and capable of forward flight, utilizing a coaxial counter-rotating rotor assembly. Furthermore, methods for controlling the aircraft in different directions, i.e. yaw and forward flight, are disclosed. Finally, some alternative aircrafts suited for special purposes or operations are disclosed.

Brief description of the drawings

The following detailed description of the preferred embodiment is accompanied by drawings in order to make it more readily understandable. In the drawings:

Figure 1 is a perspective view of a 4-bladed rotor.

Figure 2 is side views of the rotor in figure 1, showing the rotor in a horizontal and in a tilted position.

Figure 3 is side, front and bottom views of a rotor blade that can twist along its longitudinal axis.

Figure 4 is side, front and bottom views of a rotor blade comprised of two connected elements.

Figure 5 is side, front and bottom views of a rigid rotor blade resiliently connected to the rotor.

Figure 6 is a perspective view of an aircraft with a coaxial rotor assembly and a vertical thrust propeller for control.

Figure 7 is a perspective view of an aircraft employing an alternative embodiment of the present invention.

Figure 8 is a perspective view of an aircraft employing an alternative embodiment of the present invention.

Detailed description of the preferred embodiment

In the following the present invention will be discussed and the preferred embodiment described by referring to the accompanying drawings. Some alternative embodiments will be described, however, people skilled in the art will realize other applications and modifications within the scope of the invention as defined in the enclosed independent claims.

In figure 1 and 2 the preferred embodiment of a rotor according to the present invention is shown. This rotor is best suited for small aircrafts, free flying or remotely operated, indoors or under light wind conditions. The rotor consists of 4 flexible rotor blades, tiltably connected to a vertical rotor shaft in a way that creates a generally fixed conical shape and a rotating plane defined by the path the tip of the rotor blades follow when they rotate about the rotor shaft axis. The rotor is encircled by a ring connected to the tip of each rotor blade, and no individual rotor blade is allowed to flap (move up and down) separately. The ring, by definition lies in the rotating plane. There are no means for actively controlling the pitch of the blades.

A rotor as described above, is, because of the weight of the rotor blades and the ring, influenced by gyroscopic forces. Due to the effect of gyroscopic precession, a rotating object like this rotor will when it is subject to a tilting force, tilt in a transverse direction. If the rotor had been more rigidly connected to the rotor shaft and aerodynamic forces tried to tilt it relative to the shaft, it would experience mechanical forces from the connection, trying to hold it back. Because of the gyroscopic precession, the rotor would actually start to tilt sideways with respect to the initial forces holding it back. The sideways tilting would again give rise to new mechanical forces and cause the rotor to tilt in yet another direction. The rotor could easily come out of control.

From the discussion of gyroscopic forces above, it can be seen that because the rotor of the present invention has a

fixed geometry, one of the important and necessary features is that it can tilt more or less freely in any direction with respect to the rotor shaft. This of course, to reduce any mechanically introduced forces on the rotor.

Since the rotor can tilt in any direction it is essential to stabilize it. In a conventional two-bladed rotor this can be realized by introducing a so called stabilizer bar that gyroscopically controls the pitch of the rotor blades in a way that secures stability with respect to the rotor shaft.

The present invention, however, discloses a different way of obtaining stability without the use of a stabilizer bar. By utilizing a rotor blade that can twist along its longitudinal axis, so that, in case the rotor tilts about an axis parallel to the rotor blade in discussion, it will be possible for the inner part of the rotor blade to maintain a fixed pitch relative to the rotor shaft axis without substantially restricting the free tilting of the rotor. This is illustrated in figure 2.

If the rotor has been tilted, the part of the blades with more or less fixed pitch relative to the rotor shaft axis will have reduced lift when they rotate towards the point where the rotating plane is at its highest and accordingly increased lift on the opposite side. The lift is at its lowest when the blades are 90 degrees of rotation in front of the highest point. Because of the gyroscopic precession described above the rotor is tilted back to its initial position by the differences in lift, and not sideways that one could otherwise be led to believe.

To achieve passive stability in hover the rotor acts against any movements relative to the air surrounding it. In a rotor that moves horizontally, the rotor blades will have different relative airspeed along the rotation. In the part of rotation where the blades rotate forward in the same direction as the movement (the advancing blade), the relative airspeed is higher than on the opposite side (the retreating blade). It is obvious that the highest relative speed, and therefore

also the highest lift, occurs at the point where the advancing blades are pointing out to the side, perpendicular to the forward movement. The increased lift starts to tilt the rotating plane. Because of the gyroscopic precession, the increased lift on the advancing blades causes the rotating plane to tilt up in front, and not sideways.

An important feature that increases the tilting tendency of the rotor, is that the outer part of the rotor blades have a fixed pitch relative to the rotating plane and the outer ring. This can be clearly seen in figure 2. If the rotor is tilted, the pitch of the inner part of the rotor blades remain unchanged, whereas the pitch further out along the blades follow the twisting until, at the tip, they have the original pitch relative to the now tilted rotating plane.

To further increase the tilting tendency, the rotor has some degree of coning; the blades are not extending absolutely horizontally outwards from the rotor shaft but are slightly inclined upward. This coning further increases the lift on the rotor blades when they are in the front part of the rotation. Initially the rotor has a thrust, pointing directly upward. When the rotating plane starts to tilt, the thrust also tilts and thereby gets a horizontal component acting against the movement, trying to stop it. While the movement slows down, the stability of the rotor with respect to the rotor shaft, gradually brings the rotor back to a horizontal level.

The increased ability to tilt up in response to any horizontal movement, distinguishes this rotor from other rotors. It is actually the opposite of normally desired behavior of a helicopter rotor, and limits the maximum achievable forward speed.

On a conventional fixed pitch rotor, the pitch along the hole rotor blade (not only the inner part) remains fixed relative to the rotor shaft even when the rotor blades follows a tilted path. Because of this, a conventional fixed pitch rotor can be quite stable with respect to the rotor shaft,

something that is normally desired in a helicopter being actively controlled by i.e. weight shifting. Helicopters from Kaman Corporation described earlier, as well as other helicopters, are controlled by changing the pitch of the rotor blades. However, during horizontal movements the pitch are cyclically changed in order to reduce the tilting tendency, not increase it, as is the case in the present invention. Hence, no conventional rotor will tilt and act against movements relative to the surrounding air in the same way as the rotor of the present invention.

On the rotor shown in figure 1, the relative importance of the stability with respect to the rotor shaft compared to the ability to tilt up in response to a horizontal movement are influenced by; the rotational speed of the rotor, the degree of coning, weight, shape and stiffness of the rotor blades and on the ring encircling them, as well as the general geometry and weight of an aircraft employing the rotor. These factors will have to be optimized with respect to each other in order to obtain passive stability in hover.

Experience has shown that: Low rotational speed require rotor blades that are generally wider, and 50-80% wider at the root than at the tip. Low rotational speed also require more tip-heavy rotor blades or a ring encircling them. High stability with respect to the surrounding air require more coning and rotor blades that twist easily in the longitudinal direction. It can also be seen, that if the ability to tilt up in response to a horizontal movement is given to much priority, it will be difficult to enter into forward flight or to handle windy conditions. In such a case it will be necessary to alter some parts of the design or the operating parameters in order to maintain the desired behavior.

Returning to the description of the preferred embodiment and referring to figure 1, 2 and 3; the rotor (10) consists of 4 rotor blades (11) with an airfoil having the shape of a thin curved plate (12). This airfoil is chosen in order to obtain rotor blades that can easily twist and still maintain longitudinal strength. The rotor blades are connected to two

center pieces; two rotor blades (11) extending in opposite direction connected to a upper center piece (13) and the other two rotor blades oriented 90 degrees with respect to the first ones, connected to a lower center piece (14). At their tip they are connected to a ring (15) encircling the hole rotor. The blades are mounted with a predefined pitch angle of approximately 20 degrees and they are inclined upward 8-12 degrees (16) to compose a rotor with a conical shape. The orthogonally oriented center pieces are independently and pivotably connected via pins (17) to the vertical rotor shaft (18). The pivotable connection enables the torque from the rotor shaft to spin the rotor and at the same time allow each set of rotor blades to tilt (19) in the longitudinal direction. The pitch of the inner part of all the rotor blades remains fixed when the rotor tilts.

The ring (15) encircling the rotor blades has three different purposes: Firstly, it supports the rotor blades so that the pitch of the outer part of the rotor blades are fixed relative to the rotating plane of the rotor. Secondly, it protects the rotor during operation by preventing anything from coming into or between the rotor blades. Thirdly, the ring utilizing its inherent weight, secure good gyroscopic stability of the rotor even at low rotational speed.

However, despite the different purposes of the ring (15), it is important to notice that the use of such a ring does not in any way limit the present invention. It is possible to design a rotor with rotor blades according to at least one of the claims in the present invention that would function without a ring encircling it.

With reference to figure 4, a different embodiment of a rotor blade is realized. The rotor blade is comprised of two elements: A first element (21) with a fixed pitch relative to the rest of the rotor and a second element (22) with flexible or hinged connection (23) to the first one. The first element is fixed to a single center piece, a hub (24). The hub holds all of the rotor blades in the rotor and it is connected by gimbals (25) to the rotor shaft (26), thus allowing the rotor

to tilt in any direction. The second element has a more or less fixed pitch relative to the rotor shaft (26) controlled by an arm (27) and links (28), connecting it to a bar (29) extending out from the rotor shaft.

The connection point between the link (28) and the second element (22) of the rotor blade is on an axis going trough the rotor shaft and being perpendicular both to the longitudinal axis of the rotor blade and to the axis of the rotor shaft. This enables the rotor blade to tilt up and down without any relative movement of the second element. If however, the rotor tilts in the other direction (the direction, that in case of the first embodiment discussed above, would have twisted the rotor blade) the first element (21) tilts together with the rest of the rotor while the second element (22) maintains its pitch relative to the rotor shaft generally unchanged. In short, the shape of the airfoil is actually changed as a result of the tilting.

When examining the rotor blade in figure 4 and following the discussion above it can be appreciated that a rotor comprised of these rotor blades will function along the same principles as the first embodiment shown in figure 3, thereby enabling sustained flight, passively stable in hover. It can also be appreciated that this rotor will function regardless of the presence of a ring encircling it. Another important feature of this rotor blade is that it functions just as well for 2, 3, 4 and 5 bladed rotors. People skilled in the art will also realize modifications and variations of this embodiment within the scope of the invention.

With reference to figure 5, a different embodiment of a rotor blade is realized, utilizing a rigid blade (40), that in, or along its longitudinal axis, has resilient connections (41) and (42) to the rest of the rotor. The pitch of the rotor blade will then be only partly fixed relative to the rotor shaft (43) and to the ring (44), and it will depend on the stiffness of the resilient connections and the degree of rotor tilt with respect to the rotor shaft. This embodiment of the present invention actually requires an outer

connection between the tips of the rotor blades i.e. a ring similar to the one described earlier. This rotor blade, as well as the rotor blade in figure 3 is best suited for either a 2, 4 or 6-bladed rotor.

The present invention also discloses different aircrafts having coaxial, counter-rotating rotors. They are passively stable in hover and capable of forward flight at low speeds. Stable hover makes the aircrafts much more easy to operate and control. The coaxial counter-rotating rotors in addition to being very power effective also have the advantage that any gyroscopic or aerodynamic effects tends to balance each other out, adding to the simplification of control. The fixed geometry of the tiltable rotors also eliminates the need for individual flapping or lead/lag (forward and aft) movements of the rotor blades and still there are little or no vibrations in the aircraft.

With reference to figure 6 the preferred embodiment of an aircraft according to the present invention, is shown. It is a small electric powered remotely operated helicopter-like aircraft (50) having a coaxial, counter-rotating rotor. The coaxial rotor assembly consists of two rotors similar to the one disclosed in the first embodiment discussed above. The two rotors are placed one above the other utilizing an inner shaft (51) for the upper rotor (52) and an outer shaft (53) for the lower rotor (54). The main advantage of this rotor assembly is that it does not need any counteracting of the rotor torque by i.e. a tail rotor. The two rotors, rotating in the opposite direction balances each other out, hence, all the power is directed to producing lift. Because the aircraft is carrying its own substantially heavy batteries (55), it is important that the rotor assembly is very efficient and that the entire aircraft is light weight, preferably built of carbon fiber laminates or similar light weight materials.

The aircraft is remotely controlled by an operator using a transmitter with control sticks (not shown) to send control signals to a receiver (56) in the aircraft. The control signals in turn controls electric speed regulators (57)

electrically connected to 2 electric motors (58) and (59) for driving the main rotor assembly and one small electric motor (60) for driving a thrust propeller (61) adopted for tilting the aircraft. All the electronics and the motors are commercially available and considered to be prior art. The small thrust propeller (61) for control, is placed between two rods (62) extending horizontally aft from the main body (63) of the aircraft. It is orientated horizontally in order to give a vertical thrust vector (64) that could act to tilt the hole aircraft, including the rotor shaft and the rotors. The aircraft is supported by 4 flexible legs (65) extending downwards from the main body, while on the ground.

The electric motors are connected to the rotor shafts via reductions, comprised of large diameter wheels (66) on the rotor shafts and small wheels (67) on the motor shafts, the small wheels driving the large ones via rubber bands (68) of sufficient strength. The two motors driving the main rotors, run in opposite directions but have the same amount of output torque. When the speed of the motors, and subsequently the speed of the rotors are increased the thrust will eventually lift the aircraft.

Control of this aircraft is very easy:

Vertically, the aircraft is controlled by the speed (69) and (70) of the two main rotors. To climb the speed is increased, thereby the thrust from the rotor assembly increases. To descend, the speed is reduced. Because the torque driving the rotors in opposite direction is balanced and because the aircraft is passively stable, no other control inputs are required.

Yaw control, turning the aircraft from side to side, is achieved by simply increasing the speed (69) of one rotor and reducing the speed (70) of the other rotor by the same amount. The aircraft will then turn in a direction opposite to that of the rotor which has got the increased speed.

Horizontally, the aircraft is only controlled in forward and aft direction. To enter into forward flight the speed of the small thrust propeller (61) positioned at the back of the aircraft is increased. The vertical thrust (64) from this propeller acts to tilt the hole aircraft, including the rotor shaft and the main rotor assembly, thereby giving the total thrust from the main rotor a horizontal component that propels the aircraft forward. The same but opposite action will propel the aircraft in a backwards direction. If the small thrust propeller is actually it selves a small stable rotor according to the present invention, the aircraft will also be passively stable in yaw. That is, if the aircraft starts to rotate, the small rotor at the back will tilt and the initial vertical thrust from it will get a horizontal component that acts against the rotation.

Because of the rotors inherent resistance against horizontal movements, it is a limitation to the maximum achievable speed. It also need to be mentioned that Igor Sikorsky unsuccessfully used the concept with a control propeller in some of his early models. They failed when the forward speed increased and the downwash from the main rotor started to interfere with the control propeller. However, in this embodiment of the present invention, the maximum speed is low and the concept works. It can also be seen that in order to direct the aircraft sideways, it is necessary to first turn the aircraft, and then enter into forward flight in the desired direction.

All in all, these three directions of control; vertical, forward/aft and yaw (heading) adds up to be a very easy and intuitive way of operating the aircraft. And possibly the most important feature of this aircraft being: If the operator at any time during the flight looses control of the aircraft, he can just release the controls sticks back to neutral position, and the aircraft will stop and go into stable hover by itself!

Other embodiments of the invention can also be realized. With reference to figure 7 an alternative aircraft (80) can be

seen. It is very similar to the previous one, and only the differences will be discussed. In stead of having a small thrust propeller positioned out to the aft of the aircraft, the aircraft can be tilted by means of weight shifting. A separate and substantial heavy part of the aircraft, in this case its batteries (81), can be controllably moved in a horizontal direction (82) by a servo actuator (83) electrically connected to the receiver. The movement of the batteries alters the center of gravity with respect to the rotor assembly, thereby tilting the aircraft and rotor assembly to initiate and sustain horizontal flight. This aircraft is still very simple, but requires a few more electro-mechanical parts than in the case of the preferred embodiment using a thrust propeller. The principles for operating the aircraft are otherwise identical to those described above.

Yet another embodiment of the present invention is shown in figure 8. This alternative aircraft (90) is also quite similar to the previous ones, however now both the main rotors are driven from one larger electric motor (91) with a small double-wheel (92). One of the two driving rubber bands is twisted (93) in order to get the rotors to rotate in opposite directions. Because both rotors now always rotates at the same speed, yaw control is being provided by other means. At the back of the aircraft the single thrust propeller is replaced by two propellers (94) and (95) orientated orthogonally in order to provide both a vertical (96) and a horizontal thrust (97). The vertical component is adopted to tilt the aircraft in the same way as described above, and the horizontal component is adopted to provide yaw control.

Other modifications to the embodiments could be imagined. All the described aircrafts, in addition to forward flight could achieved sideways flight by utilizing means for also tilting the aircrafts sideways. Further, means for generating thrust can be small propellers, jets or any other arrangements capable of generating thrust. To obtain horizontal flight the thrust generating means can be placed close to the rotor

assembly, producing a horizontal thrust vector that propels the aircraft in the desired direction. In an other embodiment, four rotors could be used in stead of propellers in an aircraft like the one from Keyence Corporation described earlier, also providing passive stable yaw. The rotor of the present invention could be realized in combination with active cyclic pitch control in a conventional helicopter, and if needed, the helicopter could enter into passively stable hover or some kind of stable fail-safe modus.

Even if the features of the present invention are described in connection with aircrafts and helicopters, the invention would be useful in many other applications. In fact, the present invention may advantagely be utilized in all applications wherein items should remain stable in hover without requiring any active control, neither electronic nor manual. Examples of such applications could be: Advertisements purposes where the aircraft carries i.e. stickers, banners, flags, logos or display screens. Inspections of any kind where the aircraft being equipped with a set of sensors including a video camera. Film or television production, carrying microphones or cameras. Gathering any kind of environmental or metrology data using an aircraft equipped with a set of sensors, just passively drifting with the wind. Any kind of flying toy, either remotely controlled or free flying. In larger scale, different kinds of lifting operations, or police and military operations.

While the preferred embodiment of the present invention have been described and certain alternatives suggested, it will be recognized by people skilled in the art that other changes may be made to the embodiments of the invention without departing from the broad, inventive concepts thereof. It should be understood, therefore, that the invention is not limited to the particular embodiments disclosed but covers any modifications which are within the scope and spirit of the invention as defined in the enclosed independent claims.

Patent claims

1. A rotor, generating lift, at least comprising two rotor blades connected to a generally vertical rotor shaft having a central axis, said rotor having a rotating plane defined by a path that each tip of said rotor blades follow when the rotor rotates, *characterized in* that

the rotor is tiltable in all directions relative to the rotor shaft axis,

at least a part of one or more of the rotor blades having a pitch angle generally fixed relative to the rotor shaft axis,

at least a part of one or more of the rotor blades having a pitch angle generally fixed relative to the rotating plane.

2. A rotor according to claim 1, *characterized in* that

at least one of the rotor blades is made of flexible material enabling said rotor blade to twist in a longitudinal direction,

at least a part of said rotor blade having a pitch angle generally fixed relative to the rotor shaft axis and at least an other part of said rotor blade having a pitch angle generally fixed relative to the rotating plane.

3. A rotor according to claim 1, *characterized in* that

at least one of the rotor blades is comprised of two or more elements flexible or hinged connected to each other,

at least one element of said rotor blade having a pitch angle generally fixed relative to the rotor shaft axis and at least one other element of said rotor blade having a pitch angle generally fixed relative to the rotating plane.

4. A rotor according to claim 1, *characterized in* that

at least one of the rotor blades is a rigid rotor blade,

said rotor blade, in or along a longitudinal axis is resiliently connected to said rotor, having a pitch angle relative to the rotor shaft axis laying between a initial value and value fixed relative to the rotating plane.

5. A rotor according to claim 1, *characterized in* that said rotor having a generally fixed geometry without any individual rotor blade being able to flap separately.

6. A rotor according to claim 1, *characterized in* that said rotor blades are inclined upward with respect to a horizontal plane, giving the rotor a conical geometry.

7. A rotor according to claim 1, *characterized in* that two or more of said rotor blades at their tip are connected to a ring encircling said rotor.

8. A rotor according to claim 1, *characterized in* utilizing means adapted to actively control the pitch angle on at least a part of one or more of the rotor blades in order to obtain both passive stability and active control of said rotor.

9. An aircraft employing one or more rotors according to claim 1, *characterized in*:

said one or more rotors having sufficient rotational speed to generate at least a part of the required lift to provide sustained flight including passively stable hover.

10. An aircraft according to claim 9, *characterized in* that at least one means adapted to generate a controllable vertical thrust vector is connected to said aircraft at a horizontal distance from said one or more rotors, to enable controlled tilting of the aircraft.

11. An aircraft according to claim 9, having a center of gravity initially placed below said one or more rotors, *characterized in*:

a separate and substantially heavy part of said aircraft adapted for being controllably moved in a generally horizontal direction, in order to shift the center of gravity with respect to said one or more rotors, to enable controlled tilting of the aircraft.

12. An aircraft according to claim 9, *characterized in* that at least one means adapted to generate a controllable horizontal thrust vector is transversally connected to said aircraft at a horizontal distance from said one or more rotors, to provide yaw control.

13. An aircraft according to claim 9, *characterized in* that said aircraft employs two rotors, placed one above the other utilizing an inner shaft for the upper rotor and an outer shaft for the lower rotor, the said two rotors rotating in opposite direction, creating a coaxial, counter-rotating rotor assembly.

14. An aircraft according to claim 13, *characterized in* that the rotational speed of the two rotors can be controllably changed relative to each other, to provide yaw control.

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15. Use of an aircraft according to claim 9 for public relations purposes, said aircraft being able to carry any kind of marking, display or object to provide information or to catch public attention.

16. Use of an aircraft according to claim 9 for inspections purposes, said aircraft being equipped with a set of sensors and optionally a camera, transmitting pictures back to an operator controlling the aircraft.

17. Use of an aircraft according to claim 9 for gathering any kind of environmental or metrology data, said aircraft being equipped with a set of sensors, the aircraft being able to drift with the wind, transmitting data to the ground.

18. Use of one or more rotors according to claim 8 in an aircraft.

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19. A method for passively stabilizing an aircraft in hover, the aircraft employing at least one rotor, generating lift, at least comprising two rotor blades connected to a generally vertical rotor shaft having a central axis, said rotor having a rotating plane defined by a path that each tip of said rotor blades follows when the rotor rotates, *characterized in*

adapting said rotor to be tiltable in all directions relative to the rotor shaft axis, and

providing said at least one rotor with sufficient rotational speed to generate at least a part of the required lift to support said aircraft in hover, and

generating enough extra lift on at least one of the rotor blades by increasing the pitch angle on said rotor blade in accordance with the tilting of the rotating plane in order to quickly and substantially further tilt said rotating plane if the aircraft moves horizontally relative to air surrounding it, thereby altering the direction of lift from said rotor to act against the movement, and

reducing the lift on at least one of the rotor blades by fixing the pitch angle on at least a part of said rotor blade relative to the rotor shaft axis while the rotating plane is tilted, thereby gradually tilting the rotor back to a horizontal position as the movement slows down to a stop.

Abstract

The present invention discloses a rotor that enables an aircraft to be passively stable in hover. The rotor, having a generally fixed geometry is tiltably connected to its rotor shaft. It is, however, stable with respect both to the rotor shaft and to the surrounding air, thus allowing it to tilt up if the aircraft starts to move horizontally. The tilted rotor will act against the movement and stop it, whereby the rotor is tilted back to a horizontal level. The invention also discloses different aircrafts with coaxial rotor systems and methods to control them.

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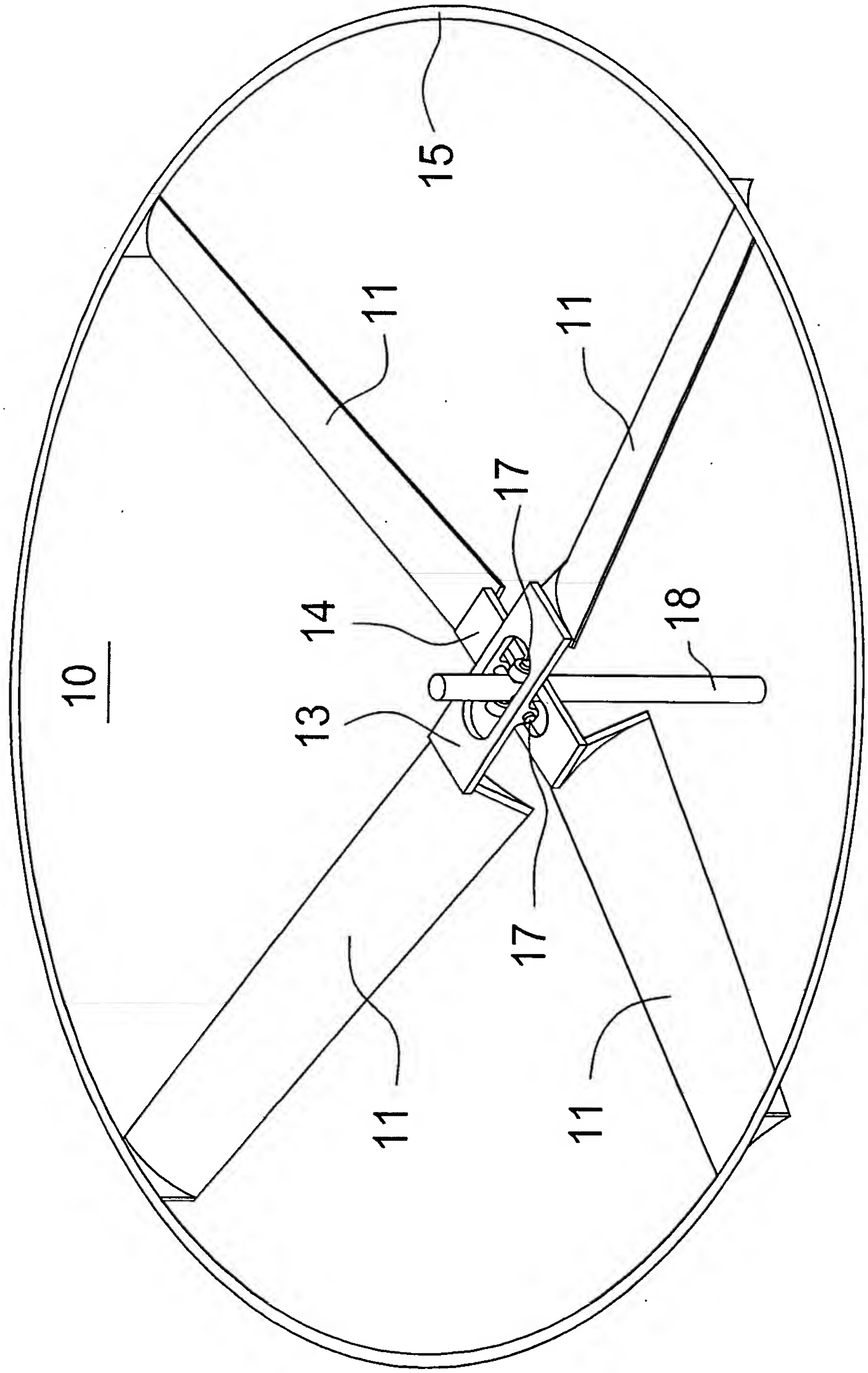


Figure 1

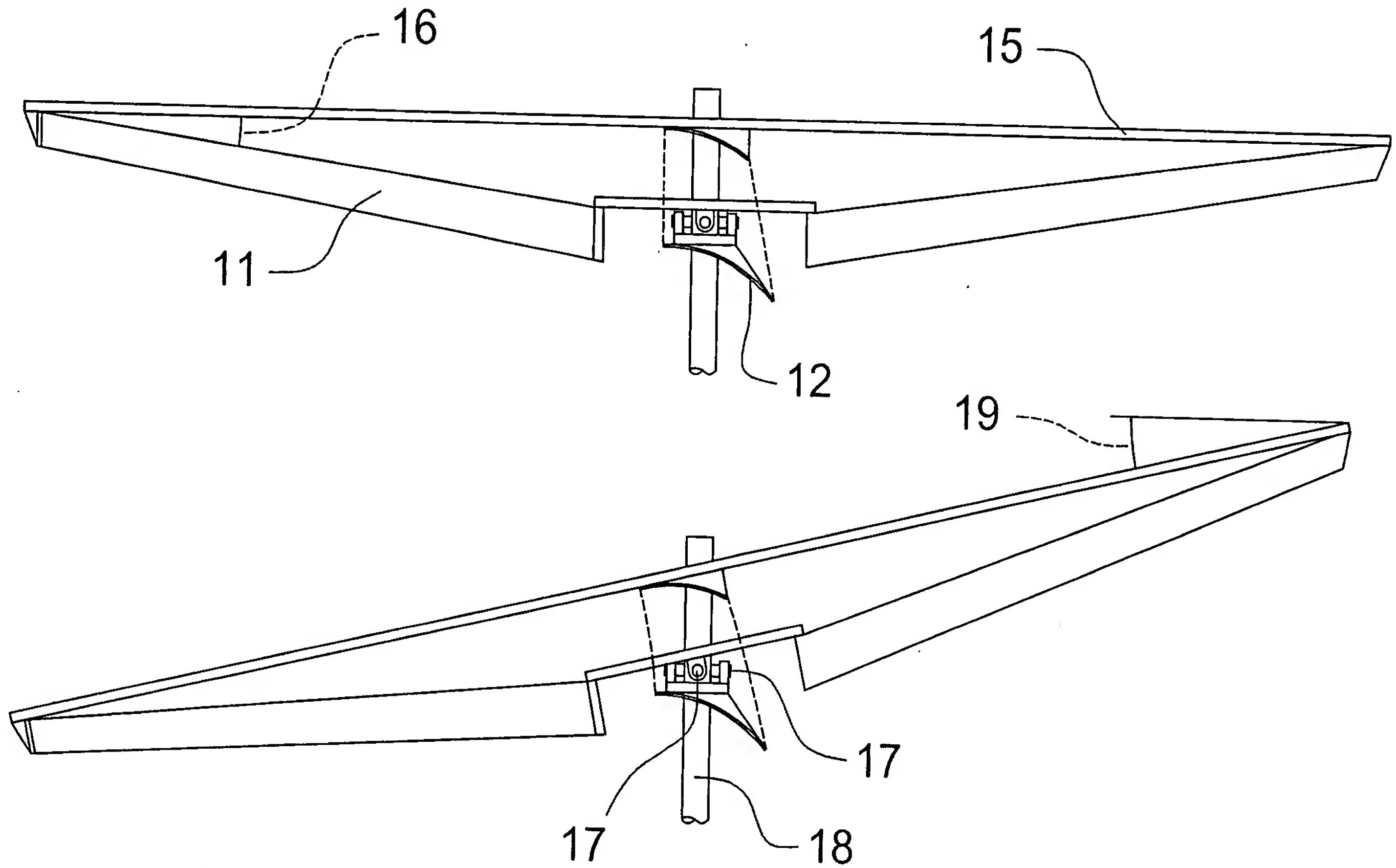


Figure 2

Figure 3

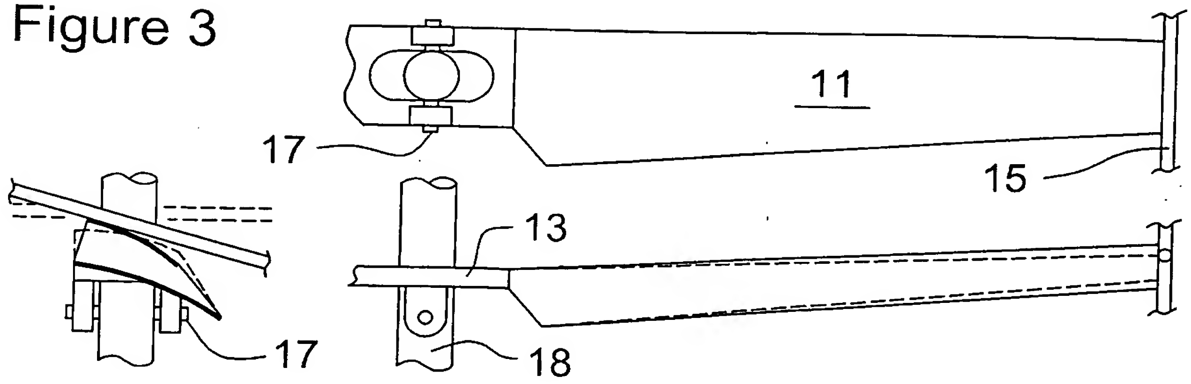


Figure 4

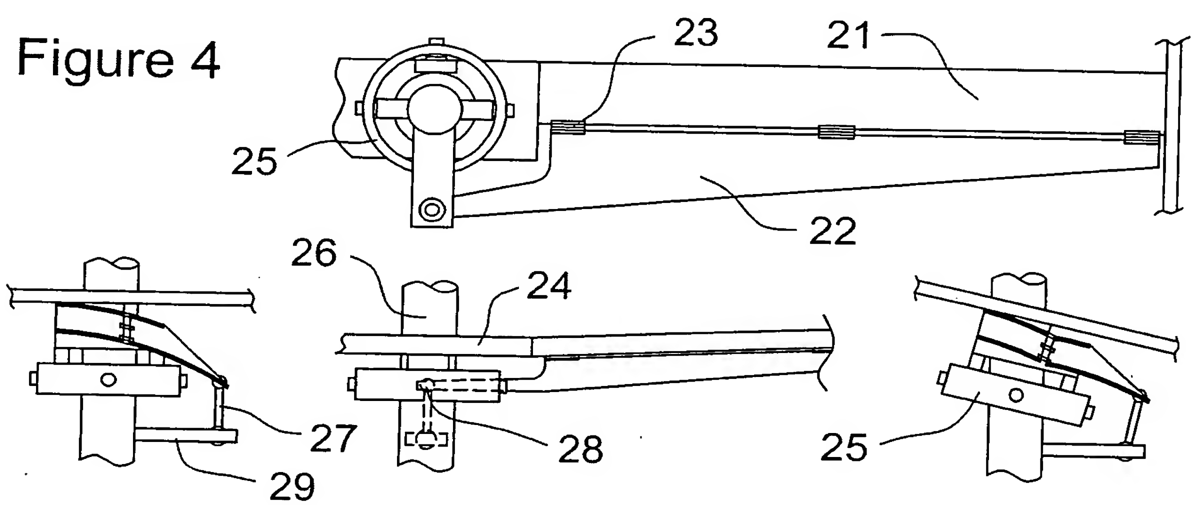
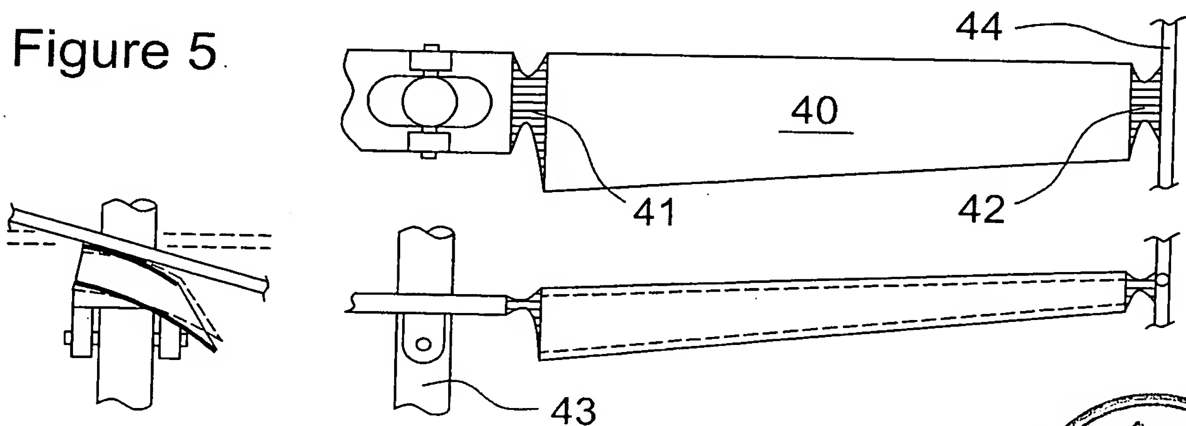


Figure 5



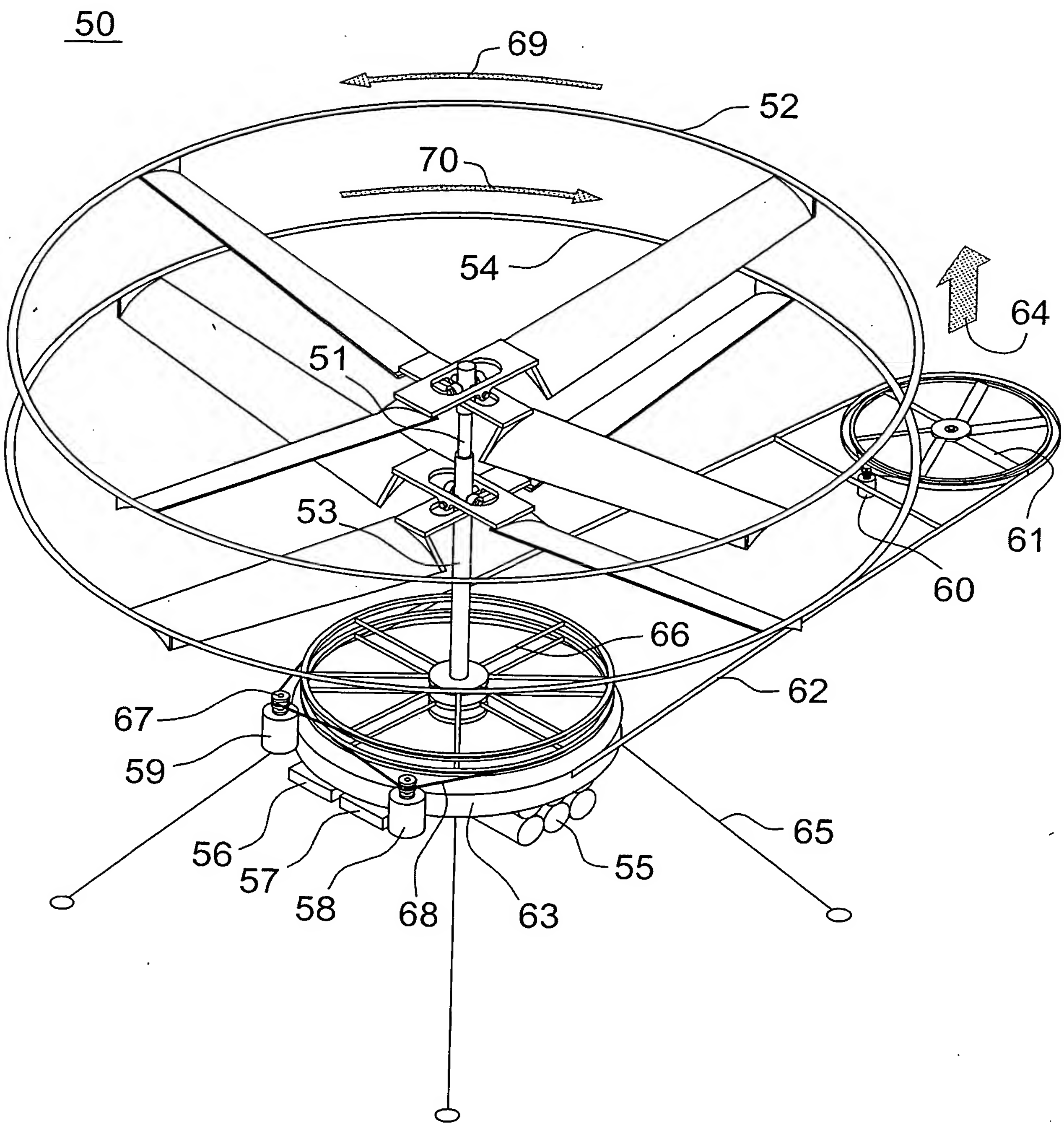

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Figure 6


PATENTSTYRET
Styret for det industrielle rettsvern

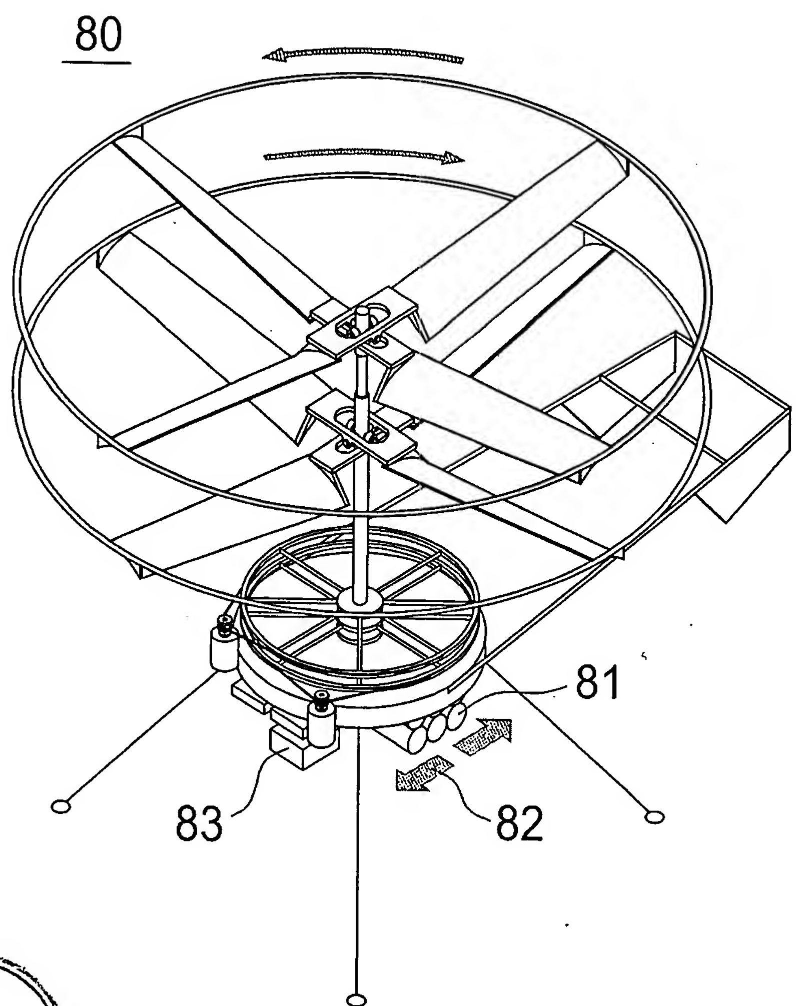

Figure 7

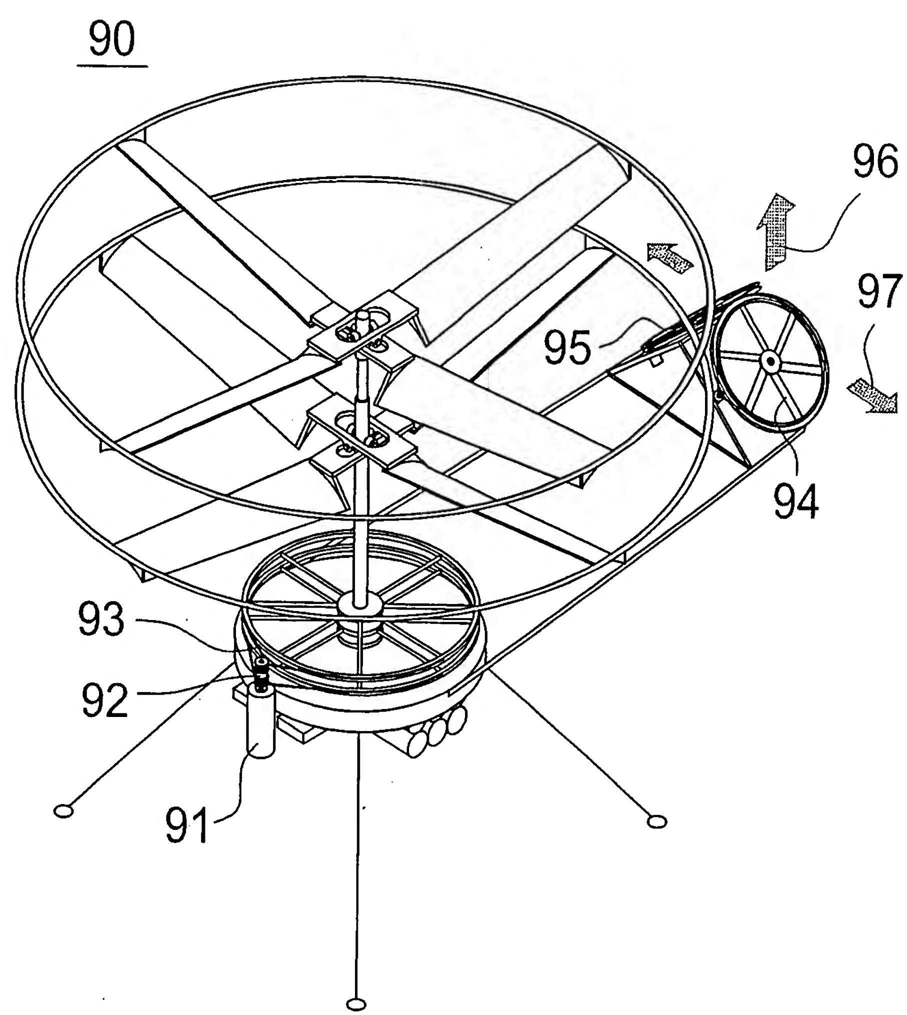

Figure 8